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Snoring and daytime sleepiness as risk factors for hypertension and diabetes in women—A population-based study

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Summary
The aim of this study was to analyze whether snoring and excessive daytime sleepiness (EDS), the main symptoms of obstructive sleep apnea syndrome (OSAS), are associated with hypertension and diabetes in women. A random sample of 6779 women aged 20–99 years answered questionnaires on sleep disturbances, daytime symptoms and somatic diseases. The women were categorized into four groups: ''no EDS or snoring'' (reference group), ''snoring but no EDS'', ''EDS but no snoring'' and ''snoring and EDS''. Prevalences of hypertension and diabetes were lowest in the reference group (8.7% and 1.6%, respectively) and highest among women with both snoring and EDS (hypertension: 26.3%, diabetes: 5.8%). In a multivariate model adjusting for age, body mass index, smoking, physical activity and alcohol dependency, ''snoring and EDS'' was a risk factor for hypertension (adjusted OR 1.82 (95% CI 1.30–2.55)) while isolated snoring or EDS was not. ''Snoring and EDS'' was more closely related to hypertension among women aged <50 years (adj. OR 3.41 (1.78–6.54) vs. 1.50 (1.02–2.19), $P = 0.01$). For diabetes, both ''EDS but no snoring'' and ''snoring and EDS'' were risk factors and the associations were most pronounced in women aged >50 years (adj. OR 2.33 (1.28–4.26) for ''EDS but no snoring'' and 2.00 (1.05–3.84) for ''snoring and EDS''). We conclude that the combination of snoring and EDS is a risk factor for hypertension and diabetes in women. For hypertension, the risk is partly age dependent and, for diabetes, EDS without snoring is a risk factor of similar

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magnitude. These differences might indicate differences in pathophysiologic mechanisms underlying the association between sleep-disordered breathing and hypertension and diabetes respectively.

Introduction

Hypertension and type 2 diabetes are two components of the metabolic syndrome. Apart from well-known risk factors, such as obesity, physical inactivity and excessive alcohol intake, there are also data indicating that both disorders are related to the obstructive sleep apnea syndrome (OSAS).[1–4]

The hypothesis that OSAS is causally related to hypertension and diabetes is supported by the fact that the successful treatment of OSAS is followed by a reduction in blood pressure[2,5] and an improvement in insulin sensitivity.[6] The underlying pathophysiologic mechanisms are not fully understood, but it can be speculated that hypoxemia, hypercapnia and/or arousal from sleep, followed by the chronic activation of the sympathetic nervous system,[7] negatively influence the metabolic and cardiovascular system. Whether negative effects on blood pressure and glucose metabolism caused by obstructive sleep apnea share similar pathophysiologic mechanisms or have different pathways remains unclear.

Snoring is one of the cardinal symptoms of OSAS. Several studies have found that snoring is positively associated with both hypertension[8–12] and diabetes.[13,14] It seems reasonable that snoring increases the risk of hypertension and diabetes through OSAS, but most snorers do not have sleep apnea.[15] Furthermore, some studies have failed to confirm snoring as an independent risk factor when age and overweight have been adjusted for.[16–18] Despite the fact that daytime symptoms are mandatory for the diagnosis of OSAS,[19] most previous studies of snoring and somatic disease have been performed without taking daytime sleepiness, into account.

The aim of this study was to analyze whether snoring and excessive daytime sleepiness (EDS), or a combination of both, are risk factors for hypertension and diabetes in a population-based sample of women.

Methods

Population

A random sample of 10,000 women aged 20 years or more living in the city of Uppsala, Sweden, was drawn from the population registry. As 14 of the women had died and 144 had moved to unknown addresses the final target population was 9842 women. A postal questionnaire was sent in April 2000, followed by reminders after 1 and 2 months, respectively. The study population comprised the 6779 subjects who returned completed questionnaires, including the questions on snoring and daytime sleepiness (response rate 68.9%).

Questionnaire

The questionnaire consisted of 109 questions on snoring, sleep disturbances, daytime symptoms and medical disorders. Body mass index (BMI) was calculated from self-reported height and weight. For questions regarding symptoms related to sleep disturbances, the subjects were asked how often they experienced specific symptoms using a five-point scale: 1 = never, 2 = seldom, 3 = sometimes, 4 = often and 5 = very often. In the question about snoring, the subjects were asked to state the frequency of their "loud and disturbing snoring". Daytime sleepiness was assessed using the question "How often do you fall asleep involuntarily for a short period during the day, for example, when there is a pause at work?". Snoring and EDS were defined as a score of 3–5.[20] Women were categorized into four groups of snoring and EDS according to Fig. 1.[21]

The subjects were asked if they had ever smoked regularly for >6 months and if they were current smokers or ex-smokers. They were asked the age at which they had started to smoke and when they had quit. Ex-smoking was considered if they had stopped smoking >6 months before inclusion. Alcohol dependency was defined as at least two positive answers to the cut down, annoyed by criticism, guilty about drinking, eye-opener drinks (CAGE) questionnaire.[22,23]

The level of physical activity during leisure time was categorized into three groups. A low level of physical activity was defined as spending most of one's time in front of the television, reading or engaging in other sedentary

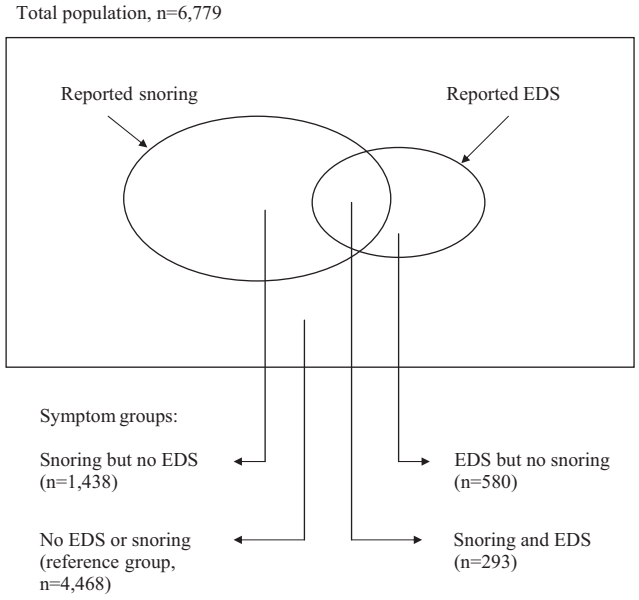

Figure 1 Approach applied to categorize the population when analyzing the risk factors for hypertension and diabetes. The percentage of subjects within each circle represents those who reported snoring and EDS, respectively. Subjects without snoring and EDS were used as a reference group.

activities. An intermediate level was scored when some physical activity like cycling or walking to work for at least 4 h a week was reported. A high level included regular physical activity like swimming, jogging, tennis, aerobic exercise for at least 3 h a week or even more vigorous activities on a weekly basis. The categorization was adopted from a large population-based, prospective study on physical activity and mortality in women.[24]

Three general questions were included about regular medical examinations, previous hospital care and medication. The subjects were classified as having hypertension if they reported attending regular medical examinations for hypertension and/or answered "Yes" to the question: "Do you have high blood pressure?". Similarly, those who answered "Yes" to the question "Do you have diabetes?" and/or said that they attended regular medical examinations for diabetes were classified as having diabetes.

The informed consent of all participants was obtained and the study was approved by the Ethics Committee at the Medical Faculty at Uppsala University.

Statistical analysis

Statistical analyses were performed using Statview® 5.0 (SAS Institute; Cary, NC, USA) and Stata® 8.0 (Stata Corporation, College Station, TX). The results are presented as the means $\pm$SD. The χ^2 test was used to test for differences between proportions. When the comparison involved continuous variables, the Mann–Whitney *U*-test was used. Multiple logistic regression analysis was performed for simultaneous evaluations of more than two variables and the results are expressed as odds ratios (OR) with 95% confidence intervals (CI). To analyze the independent influence of EDS and snoring on the somatic diseases, multivariate models were used, with adjustment for age, BMI, alcohol dependency, level of physical activity and smoking status. Multiple logistic regression analyzes were performed for the whole group and also for the younger (age <50 years) and older (>50 years) groups separately. Age was categorized into 10-year intervals in the multiple analysis, while BMI was categorized into four intervals (<20, 20–<25, 25–<30 and $\geqslant 30\,kg/m^2$). The null hypothesis was rejected at the 5% level ($P\leqslant 0.05$).

Results

The mean age of the 6779 respondents was 44.7 ± 17.2 years (range 20–99 years). Snoring was reported by 1731 subjects (25.2%) and EDS by 873 (12.9%). EDS was more common among snorers than among non-snorers (16.9 vs. 11.5%, $P<0.001$) and a total of 293 women (4.3%) suffered from both snoring and EDS (Fig. 1). Subjects with EDS and/or snoring were generally older, more frequently obese and less physically active compared with non-snoring women without EDS, whereas the prevalence of alcohol dependency did not differ significantly. Subjects reporting EDS but not snoring were more often non-smokers, while snorers without EDS were more often smokers (Table 1).

Hypertension and diabetes

Of the total population, 763 women (11.3%) fulfilled the criteria for hypertension and 157 (2.4%) the criteria for diabetes. A total of 67 females (1.0%) suffered from both hypertension and diabetes. Both hypertension and diabetes were strongly age dependent (Fig. 2).

Table 1 Characteristics of the participants by symptom group.

	No EDS or snoring ($n=4468$)	EDS but no snoring ($n=580$)	Snoring but no EDS ($n=1438$)	Snoring and EDS ($n=293$)	Total ($n=6779$)
Age	42.2 ± 16.8	45.0 ± 22.0	$50.2\pm13.9^{***}$	$55.3\pm17.8^{***}$	44.7 ± 17.2
BMI (kg/m^2)	23.4 ± 3.6	$23.7\pm3.7^{*}$	$25.8\pm4.7^{***}$	$26.4\pm5.0^{***}$	24.1 ± 4.1
BMI >30 (kg/m^2)	231 (5.2)	34 (5.9)	229 (16.0)***	55 (19.0)***	549 (8.2)
Alcohol dependency	253 (5.8)	42 (7.7)	68 (4.9)	14 (5.1)	377 (5.8)
Physical activity					
Low level	575 (13.0)	103 (18.1)**	263 (18.5)***	61 (21.2)***	1335 (19.9)
Intermediate level	2867 (64.7)	340 (59.9)*	965 (67.9)*	196 (68.1)	4368 (65.1)
High level	986 (22.3)	125 (22.0)	193 (13.6)***	31 (10.8)***	1335 (19.9)
Smoking status					
Non-smoker	2841 (63.9)	399 (69.9)**	705 (49.5)***	165 (57.3)*	4110 (61.1)
Ex-smoker	937 (21.1)	96 (16.8)*	381 (26.7)***	60 (20.8)	1474 (21.9)
Current smoking	667 (15.0)	76 (13.3)	339 (23.8)***	63 (21.9)**	1145 (17.0)

The results are presented as mean+SD or as *n* (%[a]). *P*-values calculated for differences compared with subjects with no symptoms.
*$P<0.05$.
**$P<0.01$.
***$P<0.001$.
[a]Percentage of those who responded to the actual question.

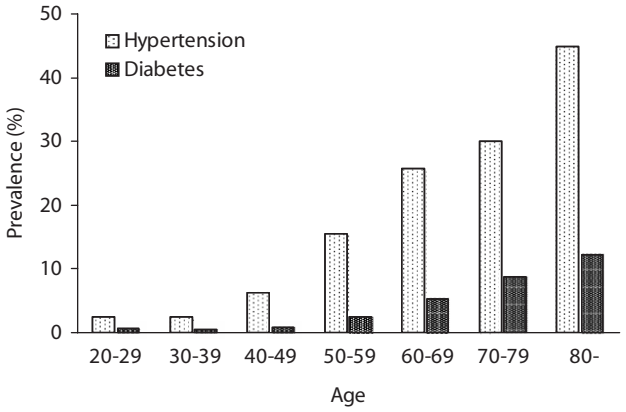

Figure 2 Prevalence of hypertension and diabetes by age group.

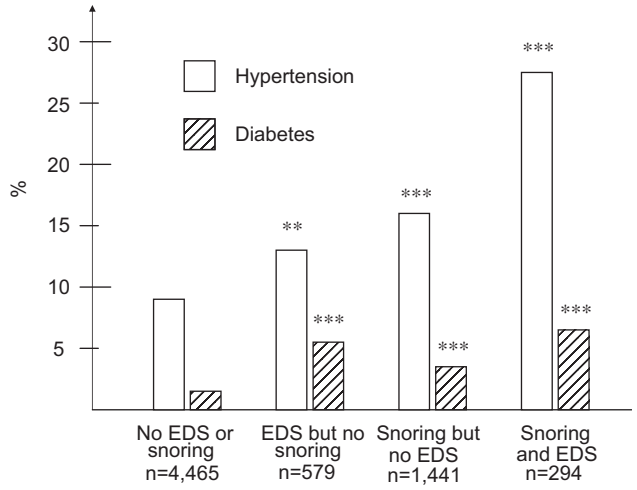

Figure 3 Prevalence of hypertension and diabetes by symptom group. $^{**}P<0.01$, $^{***}P<0.001$. *P*-values indicate differences compared to the reference group with no EDS or snoring.

The lowest prevalences of both hypertension and diabetes were found among women who reported neither snoring nor EDS (Fig. 3). In this reference group, the prevalence of hypertension was 8.7%. Of the subjects reporting EDS but not snoring, 12.8% had hypertension ($P = 0.0015$ when compared with the reference group), while the corresponding figure for the snorers without EDS was 15.5% ($P<0.0001$). The highest prevalence of hypertension was found among females who reported both snoring and EDS, 26.3% of whom suffered from hypertension ($P<0.0001$).

For reported diabetes, the prevalence in women without EDS or snoring was 1.6%, increasing to 5.0% in the group with EDS but no snoring ($P<0.0001$ compared with the reference group). In addition, snoring women without EDS had a higher prevalence of diabetes (2.9%, $P = 0.0008$) and the highest prevalence was found when EDS and snoring occurred together (5.8%, $P<0.0001$).

Several of the risk factors for EDS and snoring (Table 1) were also more common among women with hypertension and diabetes. Both diseases were associated with higher age, obesity and physical inactivity (Table 2).

Risk factor for hypertension

In the whole study population, the most prominent independent risk factor for hypertension was obesity, defined as BMI $\geqslant 30\,kg/m^2$ (Table 3). The combination of both EDS and snoring was the second most important risk factor with an adjusted OR of 1.82 (95% CI 1.30–2.55). Neither EDS without snoring nor snoring without EDS was significantly related to hypertension. Alcohol dependency and a low level of physical activity were also significant risk factors for hypertension, while smoking was not.

The combination of EDS and snoring was significantly associated with hypertension in both the younger and the older age group. However, the adjusted OR was significantly higher among women aged <50 years than among the older women (3.41 (95% CI 1.78–6.54) vs. 1.50 (95% CI 1.02–2.19), $P = 0.01$). Isolated snoring or EDS was not related to hypertension in any of the age groups. In the younger age group there was further a significant interaction between "snoring and EDS" and BMI $>30\,kg/m^2$ (adj. OR 6.3, 95% CI 1.02–39.10), while there were no other significant interactions between BMI and snoring, EDS or "snoring and EDS", respectively. Alcohol dependency was only a predictor of hypertension in younger women, while a low level of physical activity was only significantly related to hypertension in women >50 years.

Risk factors for diabetes

Obesity was an independent risk factor for diabetes. Of the symptom groups, only EDS without snoring was significantly related to diabetes in the whole population (adjusted OR 2.11 (95% CI 1.22–3.66)). For the combination of EDS and snoring, the adjusted OR was of a similar magnitude (adj. OR 1.82), but the association did not reach statistical significance (95% CI 0.97–3.43) (Table 4).

Only 23 subjects among women <50 years reported diabetes. Eleven were on insulin therapy, one on oral antidiabetic drugs and 11 did not report any medication at all. None of these diabetic women had reported the combination of snoring and EDS, while five reported snoring and three EDS. Diabetes in the younger age group was not significantly related to any of the studied risk factors. In the older age group aged $\geqslant 50$ years, both EDS without snoring and the combination of EDS and snoring were significantly associated with the risk of diabetes. Among the other studied risk factors, only obesity was significantly associated with diabetes in the older age group. For diabetes there were no significant interactions between BMI and Snoring, EDS or "snoring and EDS".

The multiple logistic regression analyses were repeated when only the 4.525 women (67%) who had answered "Yes" to the question "Do you share a bedroom with another person?" were included. The results did not change significantly from the results presented in Tables 3–4 (data not shown).

Discussion

This is the first epidemiologic study in women designed to analyze how sleep-disordered breathing (snoring) is

Table 2 Comparison of women with and without hypertension and diabetes respectively.

Variable	Hypertension			Diabetes		
	No ($n = 6016$)	Yes ($n = 763$)	*P*-value	No ($n = 6622$)	Yes ($n = 157$)	*P*-value
Age	42.4+16.2	61.0+15.7	<0.001	44.3+16.9	64.1+15.7	<0.001
BMI (kg/m^2)	23.8$\pm$4.0	26.1$\pm$4.3	<0.001	24.0$\pm$4.0	26.4$\pm$4.6	<0.001
BMI >30 (kg/m^2)	7.0	17.5	<0.001	7.9	19.6	<0.001
Alcohol dependency	5.8	4.6	0.15	5.8	4.3	0.42
Physical inactivity						
High level	21.3	8.5	<0.001	20.1	10.5	0.003
Intermediate level	64.5	70.4	0.0014	65.2	63.8	0.73
Low level	14.2	21.1	<0.001	14.7	25.7	<0.001
Smoking status						
Non-smoker	61.2	60.1	0.57	61.1	61.0	0.99
Ex-smoker	21.6	24.5	0.07	21.8	24.0	0.52
Current smoking	17.2	15.4	0.20	17.1	14.9	0.48

Results are presented as mean$\pm$SD or as %.

Table 3 Risk factors for hypertension in a population-based sample of women.

	All subjects ($n = 6200$)	<50 years ($n = 3888$)	$>$ 50 years ($n = 2312$)
BMI <20 (kg/m^2)	0.76 (0.51–1.13)	0.95 (0.52–1.76)	0.64 (0.38–1.09)
20–<25 (kg/m^2)	1	1	1
25–<30 (kg/m^2)	1.79 (1.47–2.18)	2.09 (1.38–3.16)	1.69 (1.35–2.12)
>30 (kg/m^2)	3.00 (2.29–3.93)	2.99 (1.73-5.16)	3.00 (2.19-4.10)
Alcohol dependency	1.86 (1.23–2.80)	2.02 (1.20–3.40)	1.59 (0.82–3.09)
Physical activity			
High level	1	1	1
Intermediate level	1.17 (0.87–1.58)	0.92 (0.59–1.41)	1.44 (0.94–2.20)
Low level	1.48 (1.04–2.09)	1.12 (0.64–1.94)	1.84 (1.14–2.96)
Smoking status			
Non-smoker	1	1	1
Ex-smoker	0.99 (0.80–1.23)	0.94 (0.59–1.41)	(0.79–1.27)
Current smoking	1.04 (0.81–1.34)	1.12 (0.64–1.94)	0.93 (0.69–1.27)
EDS and snoring			
No EDS or snoring	1	1	1
EDS but no snoring	1.08 (0.78–1.49)	1.24 (0.66–2.32)	1.00 (0.69–1.47)
Snoring but no EDS	1.12 (0.91–1.38)	1.04 (0.66–1.65)	1.13 (0.89–1-43)
Snoring and EDS	1.82 (1.30–2.55)	3.41 (1.78–6.54)	1.50 (1.02–2.19)

The data are presented as adjusted odds ratios (95% confidence interval).

associated with hypertension and diabetes when the occurrence of daytime sleepiness is also taken into account. The main finding in this study is that, in women, the combination of snoring and EDS is a risk factor for both hypertension and diabetes. EDS without snoring is associated with diabetes but not with hypertension, while snoring without EDS does not increase the risk of either hypertension or diabetes. The results also indicate that snoring is harmless to diabetes and hypertension in the absence of daytime sleepiness.

In previous epidemiologic studies designed to analyze whether snoring is a risk factor for hypertension, the results have diverged, as an independent association has been found by some[8–12] but not by others.[16,17] However, there are many methodological differences between the studies. The number of confounders that are adjusted for varies, as do the ages of the study populations. Most importantly, in none of these studies has the occurrence of daytime sleepiness been taken into account. To compare our data with previous studies, we re-calculated the multivariate analysis to analyze the independent association between snoring and hypertension without considering daytime sleepiness. After adjusting for age, BMI, smoking, physical activity and alcohol dependency, snoring was also significantly

Table 4 Risk factor for diabetes in a population-based sample of women.

	All subjects ($n = 6200$)	<50 years ($n = 3888$)	>50 years ($n = 2312$)
BMI <20 (kg/m^2)	0.69 (0.29–1.64)	2.09 (0.63–6.88)	0.29 (0.07–1.22)
20–<25 (kg/m^2)	1	1	1
25–<30 (kg/m^2)	1.31 (0.87–1.99)	1.71 (0.56–5.24)	1.27 (0.81–2.00)
>30 (kg/m^2)	2.20 (1.29–3.77)	1.13 (0.14–9.20)	2.26 (1.28–4.00)
Alcohol dependency	2.07 (0.86–4.96)	2.32 (0.66–8.28)	1.96 (0.57–6.68)
Physical activity			
High level	1	1	1
Intermediate level	0.67 (0.37–1.21)	0.54 (0.21–1.40)	0.85 (0.38–1.90)
Low level	0.96 (0.49–1.90)	0.19 (0.02–1.58)	1.41 (0.59–3.39)
Smoking status			
Non-smoker	1	1	1
Ex-smoker	1.07 (0.69–1.67)	1.30 (0.43–3.96)	1.02 (0.63–1.66)
Current smoker	1.13 (0.66–1.95)	1.40 (0.43–3.96)	1.14 (0.62–2.10)
EDS and snoring			
No EDS or snoring	1	1	1
EDS but no snoring	2.11 (1.22–3.66)	1.22 (0.27–5.50)	2.33 (1.28–4.26)
Snoring but no EDS	1.36 (0.87–2.13)	1.21 (0.37–3.93)	1.42 (0.87–2.32)
Snoring and EDS	1.82 (0.97–3.43)	Too few cases	2.00 (1.05–3.84)

The data are presented as adjusted odds ratios (95% confidence interval). The odds ratios are adjusted for age and for all the variables in the table.

associated with hypertension in our population with an adjusted OR of 1.4 (95% CI 1.1–1.7).

In a previous population-based, prospective study in men, we found that snoring was a risk factor for developing hypertension in men under the age of 50 but not in elderly men.[9] However, the data were later re-analyzed also to take account of the occurrence of daytime sleepiness in a manner similar to that in the present study. Also in men, only snorers who also suffered from EDS ran an increased risk of developing hypertension, while snoring alone (or EDS alone) did not influence the risk.[25] The theory that sleep-disordered breathing is only a risk factor for hypertension in symptomatic subjects is further supported by the intervention studies published so far. In sleep clinic patients with the diagnosis of OSAS, the reversal of sleep apnea by continuous positive airway pressure (CPAP) was followed by significant positive effects on blood pressure.[2,5] In contrast, CPAP does not appear to have positive effects on blood pressure when patients with sleep apnea but without daytime sleepiness are treated.[26]

The combination of snoring and EDS was a risk factor for hypertension at all ages, but the association was more pronounced in younger women. Moreover, in previous community-based studies, the association between obstructive sleep apnea or snoring and hypertension decreased with increasing age.[10,27] This is also in accordance with previous reports from clinical settings. In a sleep laboratory cohort, sleep apnea was an independent predictor of uncontrolled hypertension in patients aged <50 years, while in older patients BMI was the only independent predictor.[28] Bixler et al.[29] reported that sleep-disordered breathing was associated with hypertension in both genders, but also that the strength of this association decreased with age. In women <50 years there was further a significant interaction between "snoring and EDS" and BMI >30 for hypertension supporting the theory that the coexistence of sleep-disordered breathing and obesity may have more widespread implications for cardiovascular control and dysfunction in obese individuals.[30]

After adjusting for confounders, there was no significant association between snoring without EDS and diabetes. This might appear to be in contrast to previous prospective studies where snoring was found to be a significant risk factor for developing diabetes in both men[13] and women.[14] However, in these studies, the occurrence of daytime sleepiness was not taken into account. When re-analyzing our data without considering EDS, snoring is also independently associated with diabetes (adj. OR 1.6, 95% CI 1.1–2.7).

More recently, Shin et al. reported the results of their study designed to analyze the association between habitual snoring and glucose and insulin metabolism in non-obese men who performed an oral glucose tolerance test. The habitual snorers had significantly higher glucose and insulin levels at 2 h compared with non-habitual snorers, while fasting glucose or insulin levels did not differ significantly between the groups.[31] Furthermore, in a population-based sample of hypertensive men, the prevalence of obstructive sleep apnea was significantly higher in diabetic patients than in normoglycemic subjects, independent of central obesity.[3] In contrast, in an Italian study of obese patients, snoring was associated with diabetes in a univariate analysis, but in a multivariate analysis an independent effect of snoring was only observed for hypertension.[18] In none of the cited studies, however, was the occurrence of EDS taken into account.

In the limited number of surveys performed within this area on sleep clinic cohorts, i.e. on patients referred because of symptoms suggestive of sleep-disordered breathing, the data relaying to a significant, independent relationship between OSAS and diabetes are in greater agreement. In a sleep clinic sample of males referred for suspected sleep apnea, Strohl et al.[32] found a significant relationship between fasting insulin and the apnea-hypopnea index, independently of BMI. The data were confirmed in a more recent study by Meslier et al.,[4] who reported a significant relationship between sleep-disordered breathing and impaired glucose–insulin metabolism that was independent of obesity and age. Furthermore, in patients with severe OSAS, treatment with CPAP was followed by significantly improved insulin sensitivity.[6]

Even though the combination of EDS and snoring, i.e. the main symptoms of OSAS, was a risk factor for both hypertension and diabetes, there were also differences between the correlations to the two diseases. The association with hypertension decreased with increasing age, while the association with diabetes appeared to be similar in both age groups or even more pronounced among the elderly. Furthermore, for hypertension, only the combination of the symptoms was independently associated with hypertension, while snoring and EDS alone were not. For diabetes, on the other hand, EDS was a risk factor regardless of whether or not the subject was a snorer. One possible explanation could be that diabetes per se gives rise to daytime sleepiness and that sleep-disordered breathing does not influence the risk. However, this would then be in contrast to previous reports on significant associations between sleep-disordered breathing and impaired glucose metabolism.[4,6,32] The pathophysiology of hypertension and diabetes in sleep-disordered breathing is not fully understood and the results obtained here indicate that there are partly different underlying mechanisms that contribute to the genesis of hypertension and diabetes in OSAS, respectively. In a review of the pathophysiology of hypertension in obstructive sleep apnea, Richert et al.[33] stated that there are three components of importance: (1) large negative intrathoracic pressure, (2) intermittent hypoxemia and (3) arousal from sleep. As the severity of sleep apnea, as indicated by the maximum intraeosophageal pressure, decreases with age,[34] this might be a possible explanation of why younger patients with sleep apnea are more prone to develop hypertension. When it comes to diabetes and impaired glucose metabolism, it is known that sleep deprivation reduces insulin sensitivity[35] and has a harmful impact on carbohydrate metabolism similar to that seen in normal aging.[36,37] The frequent arousals seen in patients with OSAS might have negative consequences on carbohydrate metabolism through similar pathophysiologic mechanisms, such as sleep deprivation or sleep disruption with other causes.

One limitation of the present study is the self-reported data including the risk of recall bias and the fact that some snoring women may not be aware that they snore. However, when only subjects who shared a bedroom with another person were included, this did not significantly change any of the results. The results were adjusted for physical activity but the method used here does only include physical activity during leisure time. It is possible that some women were sedentary during leisure time and physically active during work, or reverse. Further, hypertension and diabetes are likely to be underestimated since blood pressure and blood glucose were not measured, which in turn weakens the associations. The reported figures for prevalence of hypertension and diabetes are similar to recent Swedish population studies.[38,39]

We conclude that, in an adult female population, the combination of snoring and EDS is an independent risk factor for both hypertension and diabetes, while snoring without daytime sleepiness does not influence the risk. These epidemiologic data also show significant differences between hypertension and diabetes in the way they interact with the main symptoms of OSAS. These differences might indicate that there are different underlying pathophysiologic mechanisms that contribute to the genesis of hypertension and diabetes in obstructive sleep apnea syndrome.

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References

1. Peppard PE, Young T, Palta M, Skatrud J. Prospective study of the association between sleep-disordered breathing and hypertension. *N Engl J Med* 2000;**342**:1378–84.
2. Pepperell JC, Ramdassingh-Dow S, Crosthwaite N, et al. Ambulatory blood pressure after therapeutic and subtherapeutic nasal continuous positive airway pressure for obstructive sleep apnoea: a randomised parallel trial. *Lancet* 2002; **359**:204–10.
3. Elmasry A, Lindberg E, Berne C, et al. Sleep-disordered breathing and glucose metabolism in hypertensive men: a population-based study. *J Intern Med* 2001;**249**:153–61.
4. Meslier N, Gagnadoux F, Giraud P, et al. Impaired glucose-insulin metabolism in males with obstructive sleep apnoea syndrome. *Eur Respir J* 2003;**22**:156–60.
5. Becker HF, Jerrentrup A, Ploch T, et al. Effect of nasal continuous positive airway pressure treatment on blood pressure in patients with obstructive sleep apnea. *Circulation* 2003;**107**:68–73.
6. Harsch IA, Schahin SP, Bruckner K, et al. The effect of continuous positive airway pressure treatment on insulin sensitivity in patients with obstructive sleep apnoea syndrome and type 2 diabetes. *Respiration* 2004;**71**:252–9.
7. Carlson JT, Hedner J, Elam M, Ejnell H, Sellgren J, Wallin BG. Augmented resting sympathetic activity in awake patients with obstructive sleep apnea. *Chest* 1993;**103**:1763–8.
8. Gislason T, Åberg H, Taube A. Snoring and systemic hypertension—an epidemiologic study. *Acta Med Scand* 1987;**222**: 415–21.
9. Lindberg E, Janson C, Gislason T, Svärdsudd K, Hetta J, Boman G. Snoring and hypertension: a 10 year follow-up. *Eur Respir J* 1998;**11**:884–9.
10. Koskenvuo M, Partinen M, Sarna S, Kaprio J, Langinvainio H, Heikkilä K. Snoring as a risk factor for hypertension and angina pectoris. *Lancet* 1985;**1**:893–6.
11. Gislason T, Benediktsdottir B, Björnsson J, Kjartansson G, Kjeld M, Kristbjarnarson H. Snoring, hypertension, and the sleep apnea syndrome an epidemiologic survey of middle-aged women. *Chest* 1993;**103**:1147–51.
12. Hu FB, Willett WC, Colditz GA, et al. Prospective study of snoring and risk of hypertension in women. *Am J Epidemiol* 1999;**150**:806–16.

13. Elmasry A, Janson C, Lindberg E, Gislason T, Tageldin MA, Boman G. The role of habitual snoring and obesity in the development of diabetes: a 10-year follow-up study in a male population. *J Intern Med* 2000;**248**:13–20.
14. Al-Delaimy WK, Manson JE, Willett WC, Stampfer MJ, Hu FB. Snoring as a risk factor for type II diabetes mellitus: a prospective study. *Am J Epidemiol* 2002;**155**:387–93.
15. Gislason T, Taube A. Prevalence of sleep apnea syndrome—estimation by two stage sampling. *Ups J Med Sci* 1987;**92**: 193–203.
16. Jennum P, Sjöl A. Snoring, sleep apnea and cardiovascular risk factors: the MONICA II study. *Int J Epidemiol* 1993;**22**:439–44.
17. Koskenvuo M, Partinen M, Kaprio J, et al. Snoring and cardiovascular risk factors. *Ann Med* 1994;**26**:371–6.
18. Marchesini G, Pontiroli A, Salvioli G, et al. Snoring, hypertension and type 2 diabetes in obesity. Protection by physical activity. *J Endocrinol Invest* 2004;**2**:150–7.
19. Sleep-related breathing disorders in adults: recommendations for syndrome definition and measurement techniques in clinical research. The report of an American Academy of Sleep Medicine Task Force. *Sleep* 1999;**22**:667–89.
20. Lindberg E, Carter N, Gislason T, Janson C. Role of snoring and daytime sleepiness in occupational accidents. *Am J Respir Crit Care Med* 2001;**164**:2031–5.
21. Lindberg E, Janson C, Svärdsudd K, Gislason T, Hetta J, Boman G. Increased mortality among sleepy snorers: a prospective, population based study. *Thorax* 1998;**53**:631–7.
22. Mayfield D, McLeod G, Hall P. The CAGE questionnaire: validation of a new alcoholism screening instrument. *Am J Psychiatry* 1974;**131**:1121–3.
23. Beresford TP, Blow FC, Hill E, Singer K, Lucey MR. Comparison of CAGE questionnaire and computer-assisted laboratory profiles in screening for covert alcoholism. *Lancet* 1990;**336**:482–5.
24. Lissner L, Bengtsson C, Bjorkelund C, Wedel H. Physical activity levels and changes in relation to longevity. A prospective study of Swedish women. *Am J Epidemiol* 1996;**143**:54–62.
25. Lindberg E. Snoring and sleep apnea. A study of evolution and consequences in a male population. Minireview based on doctorial thesis. *Uppsala J Med Sci* 1998;**103**:155–202.
26. Barbe F, Mayoralas LR, Duran J, et al. Treatment with continuous positive airway pressure is not effective in patients with sleep apnea but no daytime sleepiness. a randomized, controlled trial. *Ann Intern Med* 2001;**134**:1015–31.
27. Nieto FJ, Young TB, Lind BK, et al. Association of sleep-disordered breathing, sleep apnea, and hypertension in a large community-based study. Sleep Heart Health Study. *JAMA* 2000;**288**:1829–36.
28. Grote L, Hedner J, Peter JH. Sleep-related breathing disorder is an independent risk factor for uncontrolled hypertension. *J Hypertens* 2000;**18**:679–85.
29. Bixler EO, Vgontzas AN, Lin HM, et al. Association of hypertension and sleep-disordered breathing. *Arch Intern Med* 2001;**161**:2634–5.
30. Wolk R, Shamsuzzaman AS, Somers VK. Obesity, sleep apnea, and hypertension. *Hypertension* 2003;**42**:1067–74.
31. Shin C, Kim J, Kim J, et al. Association of habitual snoring with glucose and insulin metabolism in non-obese Korean adult men. *Am J Respir Crit Care Med* 2005;**171**:287–91.
32. Strohl KP, Novak RD, Singer W, et al. Insulin levels, blood pressure and sleep apnoea. *Sleep* 1994;**17**:614–8.
33. Richert A, Ansarin K, Baran AS. Sleep apnea and hypertension: pathophysiologic mechanisms. *Semin Nephrol* 2002;**22**:71–7.
34. Krieger J, Sforza E, Boudewijns A, Zamagni M, Petiau C. Respiratory effort during obstructive sleep apnea. Role of age and sleep stage. *Chest* 1997;**112**:875–84.
35. Gonzalez-Ortiz M, Martinez-Abundis E, Balcazar-Munoz BR, Pascoe-Gonzalez S. Effect of sleep deprivation on insulin sensitivity and cortisol concentration in healthy subjects. *Diab Nutr Metab* 2000;**2**:80–3.
36. Scheen AJ, Byrne MM, Plat L, Leproult R, Van Cauter E. Relationships between sleep quality and glucose regulation in normal humans. *Am J Physiol* 1996;**2**(Pt 1):E261–70.
37. Spiegel K, Leproult R, Van Cauter E. Impact of sleep dept on metabolic and endocrine function. *Lancet* 1999;**9188**:1435–9.
38. Jansson JH, Boman K, Messner T. Trends in blood pressure, lipids, lipoproteins and glucose metabolism in the Northern Sweden MONICA project 1986–99. *Scand J Public Health Suppl* 2003;**61**:43–50.
39. Brohall G, Behre CJ, Hulthe J, Wikstrand J, Fagerberg B. Prevalence of diabetes and impaired glucose tolerance in 64-year-old Swedish women: experiences of using repeated oral glucose tolerance tests. *Diab Care* 2006;**29**:363–7.